



UWS Academic Portal

Comparison of environmental life cycle analysis of aluminium alloy (LM 6) street light housing and aluminium alloy (AL Si12Cu1{Fe}) housing

Chinombo, Maxford; Vichare, Parag; Cheung, Wai Ming

Published in:
Renewable and Sustainable Energy Developments Beyond 2030

Published: 08/05/2018

Document Version
Publisher's PDF, also known as Version of record

[Link to publication on the UWS Academic Portal](#)

Citation for published version (APA):
Chinombo, M., Vichare, P., & Cheung, W. M. (2018). Comparison of environmental life cycle analysis of aluminium alloy (LM 6) street light housing and aluminium alloy (AL Si12Cu1{Fe}) housing. In A. G. Olabi (Ed.), *Renewable and Sustainable Energy Developments Beyond 2030: Proceedings of the 11th International Conference on Sustainable Energy & Environmental Protection* (Vol. 1, pp. 7-12). University of the West of Scotland.

General rights

Copyright and moral rights for the publications made accessible in the UWS Academic Portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

If you believe that this document breaches copyright please contact pure@uws.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.



UWS UNIVERSITY OF THE
WEST of SCOTLAND

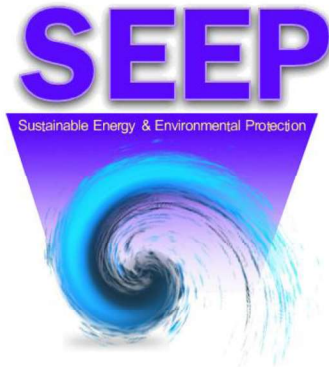
Institute of Engineering and
Energy Technologies

RENEWABLE AND SUSTAINABLE ENERGY DEVELOPMENTS BEYOND 2030

VOLUME 1

SEEP CONFERENCE 2018

University of the West of Scotland, Paisley Campus
Tuesday 8-Friday 11 May 2018



Renewable and Sustainable Energy Developments Beyond 2030

VOLUME 1

***Proceedings of the 11th International Conference on
Sustainable Energy & Environmental Protection***

EDITED BY:

Prof Abdul Ghani Olabi

University of the West of Scotland

School of Engineering & Computing

Institute of Engineering & Energy Technologies

© Abdul Ghani Olabi 2018

“Renewable and Sustainable Energy Developments Beyond 2030

VOLUME 1”

First Published in 2018

by

University of the West of Scotland

High Street, Paisley, PA1 2BE

UK

The authors have asserted their moral rights

ISBN: 978-1-903978-60-3

All rights reserved.

Table of Contents

Environmental Protection and Sustainability

A systems analysis of multilateral international cooperation on industrial production capacities: a case study of iron and steel Xiaodong M., Linwei M., Pei L., Zheng L., Weidou N.	1
Comparison of environmental life cycle analysis of aluminium alloy (Im 6) street light housing and aluminium alloy (Al Si12Cu1{Fe}) housing Maxford Chinombo, Parag Vichare, Wai Ming Cheung	7
Renewable production of acrolein by catalytic dehydration of glycerol over commercial hy zeolites Israel Pala R., José L. Contreras, Sofia Hernández R., José Salmones B., Ricardo López M., Andrés A. Fragoso Montes de Oca, Jennipher Pérez C.	13
Development of an automatic control algorithm for the window ventilation system using a logistic regression model Hakpyeong Kim, Taehoon Hong, Jeongyoon Oh, Kwangbok Jeong, Jimin Kim	19
Effect of different levels of lead on soil enzymatic activity and restoration by resistant bacteria M. Manzoor ¹ , I. Gul, J. Kallerhoff, M. Arshad	25
A progressive use of BIM for energy renovation of office buildings: establishing information requirements for decision-making in sustainability assessment G. Stegnar, T. Cerovšek	31
Effect of swirling flow on heavy fuel oil combustion in a swirling flame Xinyan Pei, Long Jiang, Saumitra Saxena, Kamal M. AlAhmadi, William L. Roberts	37
A review of the application of technology roadmap in China's clean coal utilization and alternative information assistant tools Dali Zhou, Pei Liu, Linwei Ma, Chinhao Chong, Zheng Li, Weidou Ni	43
A strategic assessment on eclectic continuum of coal fly ash utilization Anjani R. K. Gollakota, Vikranth Volli, Chi-Min Shu, Nanda Kishore	51
The development of smart energy towns in china: the concept and practices Xuesheng Liang, Linwei Ma, Chinhao Chong, Zheng Li, Weidou Ni	57
Water-energy nexus: economic, social & environmental perspectives Layla Saleh, Mohammad al Zaabi, I-Tsung Tsai, Toufic Mezher	63
Endophyte assisted naphthalene biodegradation kinetics: a pilot scale investigation Aneela Iqbal, Muhammad Arshad	69
Geographical distribution of agricultural residues, co-products and by-products in the EU28 Robert Bedoić, Boris Cosić, Neven Duić	75

Thermal performance evaluation of a heat therapy tent for the control and management of citrus greening disease M.A. Basunia, Siti Simaa Suhaillina Binti Azmi	81
Cleaner seawater reverse osmosis processes with less carbon emission Jongmin Jeon, Minseok Kim, Suhan Kim.....	87
Alterations in metabolic profiles of wheat and rice grains induced by tio ₂ nanoparticles spiked soils Zahra Zahra, Muhammad Arshad, Aneela Iqbal, Hyung-Kyoon Choi	91
The path to development of an integrated tool for district cooling systems modelling, simulation, and control A. Mohammadi, R. Sterling, and M.M. Keane	97
Enhancing the thermal performance of vehicle cooling modules using diffusers - toward energy consumption and CO ₂ emission reduction M Khaled, C. Castelain, J. Faraj, M. Ramadan	103
Energy performance of residential buildings: housing case study in southern Algeria I. Laib, A. Hamidat, K. Kaced, M. Haddadi, A. Alanazi, A.G. Olabi	107
Experimental study on organic rankine cycle system with radial inflow turbine utilizing R245FA A. Tan Wu, B. Xinling Ma, C. Xinli Wei, D. Xiangrui Meng, E. Xiang Qin, F. Rong He ..	113
Bimetallic catalysts for the hydrogenolysis of HMF to produce DMF and DMTHF N. Viar, J. Requies, I. Agirre, A. Iriondo, P.L. Arias	119
The first commercialized micro-grid in china: systems anlaysis and policy discussion Min He, Linwei Ma, Zheng Li, Pei Liu, Weidou Ni	125
Comparative study of bare and annealed stainless steel substrates after electrochemical analysis in sea water M. Kovendhan, Kang Hari, Sangmin Jeong, Jong-Sang Youn, Ki-Joon Jeon	131
Transparency in energy consumption through blockchain technology for the internet of things era J. Ordieres-Meré, Fadi Shrouf	137
Electromagnetic field and audible noise emissions reduced by optimal conductor placement of 400 kv overhead power line K. Deželak	143
A systems concept to study energy strategy for sustainable development: an integration of sustainability, energy systems, social governance and market operation L.W. Ma, C. H. Chong, X. Zhang, S. Z. Song, Z. Li, W. D. Ni	149

Preparation and characterization of pitch-derived activated carbon fibers for high performance evaporated-fuel-trap of automobiles H.M. Lee, B.H. Lee, S.J. Park, S.C. Jung, B.J. Kim	157
Parametric performance analysis of high efficiency buildings: inverse modelling to link effectively design and operation practices L. Tronchin, M. Manfren, B. Nastasi	163
Decarbonisation of building stock: data analysis techniques to extract useful insights for the support of renovation processes L. Tronchin, M. Manfren, B. Nastasi	169
Particle size influence on hazard gases emission of bituminous coal spontaneous combustion during high temperature J.Y. Zhao, Y.N. Zhang, J. Guo, X.Z. Zheng, C.M. Shu	175
Revealing the energy consumption model by an enhanced clustering algorithm R.H. Lin, Z.Z. Ye Budan Wu	181
Impact of metering advancements on energy access assessment Manojit Ray Basab Chakraborty	187
Hybrid microalgae-activated sludge system for carbon-efficient wastewater treatment Kasim Mohammed, S. Z. Ahammad, P. J. Sallis, C. R. Mota	193
Using heat recovered from exhaust gases to dry fruits Rafat Al Afif, Rabih Murr, Martin Wendland, Mohamad Ramadan, Mahmoud Khaled	199
Process for the conversion of co, NO _x and CO ₂ from the emission of a boiler, utilizing catalytic converters and airlift bioreactors with the microalga <i>Scenedesmus dimorphus</i> Citlalli Arroyo, José L. Contreras, Clementina Ramírez	205
A review on polymer flooding in enhanced oil recovery under harsh conditions Shahenda Mahran, Attia Attia, Basudeb Saha.....	211
Chlorine removal from pyrolysis process of mixed plastic wastes K.Cheenkachorn, J. Thawornprsert	217
Design of coal water slurry (CWS) electrolytic desulfurization system Mingyang Yang, Junbo Zhou, Jianfeng Yang	223
Photocatalytic mitigation of two herbicides (aclonifen and picolinafen) in drinking water using ZnO in slurry photoreactor G. Pérez-Lucas, J. M. Salmerón, N. Vela, G. Navarro1, J. Fenoll, S. Navarro	229

Photodegradation of neonicotinoid insecticides in agro-waste water using $\text{TiO}_2/\text{Na}_2\text{S}_2\text{O}_8$ at pilot plant scale under natural sunlight J. Fenoll, I. Garrido, J.J. Guirao, P. Flores, P. Hellín, N. Vela, G. Navarro, S. Navarro	234
Efficient solar water-splitting using WO_3 photoanodes prepared by hydrothermal method in air and nitrogen atmosphere T. Soltani, A. Tayyebi, B.-K. Lee	239
Solar detoxification of water polluted with fungicide (myclobutanil and boscalid) residues by photo-fenton treatment Nuria Vela, Gabriel Pérez-Lucas, Ainhoa Candela, Ginés Navarro, José Fenoll, Simón Navarro	244
Assessment of the oceanic current energy potential on environmentally sensitive areas of the mexican caribbean I. Mariño-Tapia, R. Silva, C. Enriquez, A. Souza, J. López-González, J. Candela, J. Sheinbaum	249

Energy Efficiency in Process Industry

Energy efficiency in the process industry – any lessons to be learnt? J. Malinauskaite, L. Ahmad, A. Chauhan, H. Jouhara	254
Experimental investigation of heat pipe shelves used in open refrigerated display cabinet Hussam Jouhara, Nicolas Serey, Heba Ghazal, Sulaiman Almahmoud, Amisha Chauhan, Bertrand Delpech, Stephen Lester	260
The optimization of area-wide plant layout with piecewise steam pipeline network using parallel genetic algorithm based on geosteiner Y. Wu, S. Zhang, Y.F. Wang, X. Feng	266
Is the exergetic efficiency of the energy sector affected by the R&D capital? A comparative analysis for Germany and UK H. Khajepour, G. Tsatsaronis, Y. Saboohi	272
A trnsys simulation of a UK based solar PV/T collector for production of electrical power and heat over different seasons of the year Navid Khordehgah, Amisha Chauhan, Hussam Jouhara, Stephen P. Lester	279
Development of a passive loop thermosyphon for free cooling of data center Chayan Nadjahi, Hasna Louahlia, Stéphane Le Masson	285
Heterogeneous photocatalytic degradation and hydrogen evolution from ethanolamine nuclear waste water by liquid phase plasma process K.-H. Chung, S.-C. Jung	291
Experimental investigation on a radiative heat pipe heat exchanger S. Almahmoud, A. Chauhan, B. Delpech, R.T. Llera, F. Lago, J. J. Arribas, H. Jouhara	297

Thermal performance and environmental impact of an innovative exterior masonry wall system A. Kyriakidis, A. Michael, R. Illampas, D.C. Charmpis, I. Ioannou	303
Energy efficiency assessment in an industrial heat treatment process: waste heat recovery and minimization I. Bonilla, N. Nieto, L. del Portillo, B. Egilegor, H. Gaztañaga	309
Study of a small size combined orc-rankine cycle M. Marion, H. Louahlia	315
The change of product gas composition over height of the gasification reactor of a dual fluidized bed steam gasification pilot plant A. M. Mauerhofer, J. C. Schmid, F. Benedikt, H. Hofbauer	321
A fully automated calibration methodology for latest generation of automotive diesel engines P. Arya, F. Millo, F. Mallamo	327
Low NO _x - LPG staged combustion double swirl flames A.M. Elbaz, A.A. Khateeb, W.L. Roberts	333
Optimizing DESS energy distribution in time Tomaž Kramberger, Dušan Kragelj, Bojan Rupnik, Darko Goričanec	339
Use of gasoline -acetylene mixtures at different excess air ratios in an SI engine Mehmet İlhan İlhak, Selahaddin Orhan Akansu, Selim Tangöz, Nafiz Kahraman	345
Direct numerical simulations of lean premixed turbulent h ₂ /air flames in the distributed reaction zone regime Xujiang Wang, Yongliang Xie, Tai Jin, Kai H. Luo	353
Gasification of refuse-derived fuel in a pilot-scale two-stage linkage system of fluidized bed gasifier and cyclone-melting furnace Lingqin Liu, Yaji Huang, Changqi Liu, Jianhua Cao, Lu Dong, Ligang Xu, Jianrui Zha	359

COMPARISON OF ENVIRONMENTAL LIFE CYCLE ANALYSIS OF ALUMINIUM ALLOY (LM6) STREET LIGHT HOUSING AND ALUMINIUM ALLOY (AL Si12Cu1{Fe}) HOUSING

Maxford Chinombo ^{1,2}, Parag Vichare ², Wai Ming Cheung ³

1. Department of Mechanical Engineering, The Malawi Polytechnic, Malawi; Email: mchinombo@poly.ac.mw
2. School of Mechanical and Manufacturing Engineering, University of the West of Scotland, Paisley, UK; Email: Parag.Vichare@uws.ac.uk
3. Faculty of Engineering and Environment, Northumbria University, Newcastle Upon Tyne, UK; Email: wai.m.cheung@northumbria.ac.uk

ABSTRACT

The environmental impact of the re-manufactured aluminium alloy (LM6) street lamp has been analysed. The results have been compared to the new housing lamp made of aluminium alloy (Al Si12Cu1 {Fe}). The methodology used to calculate life cycle inventory and environmental impact is BEES V4.07 and Ecoinvent V3 was used as reference since it is the most updated database. The results show that the reworked aluminium lamp has an environmental impact of 2.38 pts and compared to that of alloy (Al Si12Cu1 {Fe}) which has an impact of 2.56 pts. The first major factor is that the housing remanufacturing process does not consider the primary production processes of mining, extraction and casting. The new housing includes the primary production processes and casting thus impacting heavily on the environment. The second major factor that contributes to the lower impact of the remanufactured housing than the new housing is the low energy use since the housing is not remanufactured by re-casting which is basically a re-cycling process.

Keywords: life cycle analysis, aluminium housing, light emitting diode, high pressure sodium.

1. INTRODUCTION

This study aims to determine the environmental impact of two street light aluminium housings. One City Council in UK is to embark on a project to replace high pressure sodium (HPS) street lights with light emitting diode (LED) street lights. This is due to the high energy consumption of the old lights. It is estimated that the replacements will make savings in energy, carbon emissions and maintenance among others [1].

Environmental benefits can be comprehensively assessed using life cycle analysis (LCA). Environmental impact assessment of a product considers the whole life of the product from cradle to grave. It is the way the product impacts on the ecosystem or environment through production to disposal that can then be judged as friendly or not. This assessment method has become popular in recent years due to the holistic approach to environmental assessment [2]. It quantifies the level of impact on the environment.

Aluminium contributes 3% of total global carbon emissions for material productions.[3]. Thus any reduction in aluminium material production would result in significant cuts in carbon dioxide emissions and in the environmental impact in general. Additionally, reduction in aluminium material production can also be achieved by alternative production such as recycling, re-use and remanufacturing. Remanufacturing is therefore one of the mean to be considered in order to reduce

the environmental impact of a product. Environmental impact of aluminium and aluminium products is also affected by the alloying of the aluminium material. The environmental impact of aluminium alloying elements composition differs significantly [4]. The alloying elements that create the highest environmental impact are copper, silicon and tin, elements which are commonly used in aluminium alloys. Material composition has to be taken into consideration when product environmental impact.

Recycling scenarios using LCA have been analysed on LED lighting aluminium housing produced by Zalux [5]. The housing and mechanical components were taken into account. The analysis focused on the material selection process and the end of life of the mechanical parts. The electrical components were not considered in the analysis. Products that are similar in major material terms and functionality (eg. LEDs) may have different environmental impacts based on the other components in the assembly such as connectors and driver circuit [6].

This study aims to quantify the environmental impact of a remanufactured aluminium alloy street light housing and compare the results to that of a different new aluminium alloy street lighting housing. ISO standards 14040 and 14044 of LCA have been applied. It is to provide information on which product is environmentally friendly and assist in making a decision. The LCA is however not part of a decision making process but assists in decision making [7].

2. LCA METHODOLOGY

2.1. Product Structure

The methodology in this study has been chosen based on the products structures the old lamp has a different structure and composition from the new one. The product structures and differences are shown in the figure 1

After remanufacturing the old lamp the structure will change. The electrical components will be replaced by an LED module similar to the one in the new lamp. This change has a very significant effect on the environment and hence cannot be ignored in the analysis. Thus the replacement of the bulb and holder, cables, capacitor, igniter, ballast and plastic parts will have an effect on the environment because of their end life and consequently the waste scenarios. The new LED comes complete with LED module and housing. Figure 1 shows the old lamp structures of the two products.

2.2. System Boundaries

In LCA, it is traditional to analyse the product from cradle to grave. In this study the interest is on the impact of the remanufactured housing. The new LED which is being compared with is being procured as a complete product. Therefore, the products have different boundary specifications. The remanufactured housing does not have the raw materials extraction considered. The new LED assembly have the upstream processes considered. The downstream stages of use and end life have not been considered. Figure 1 shows the production sequence for the remanufacture housing.

2.3. Life Cycle Inventory (LCI)

2.3.1 Modelling Scenarios

In order to model a product LCA the LCI has to be established. The input data was collected about the old housing and the new lamp. The old housing data includes the housing and the electrical components. Electrical components for the old lamp are replaced by the new LED lamp and the associated circuits. Below are the modelling methodologies which have been used.

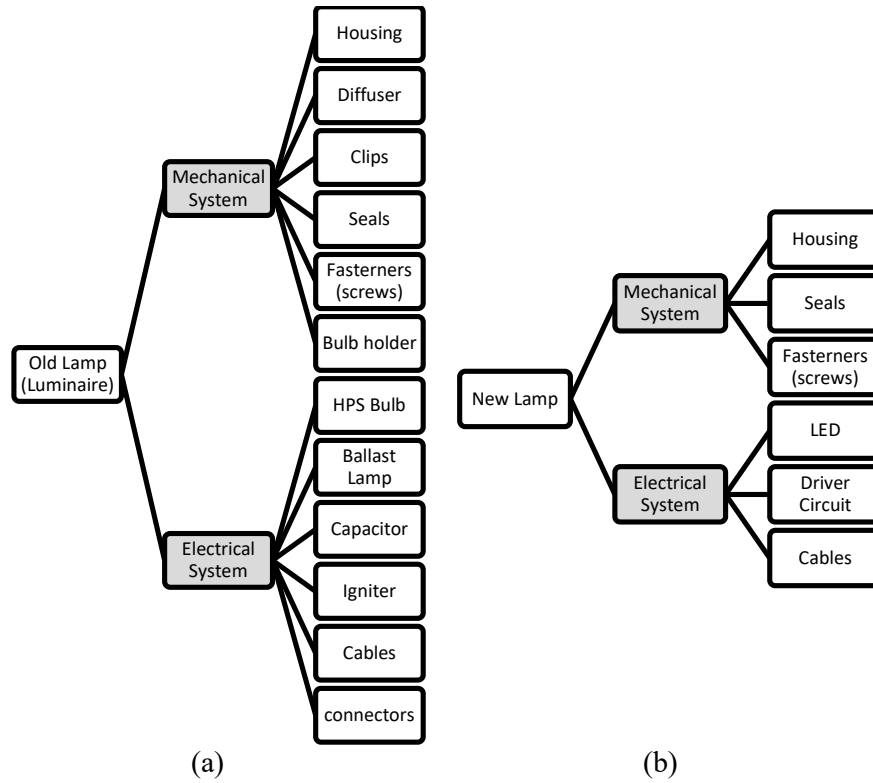


Figure 1: Product Structure (a) Old HPS lamp (b) New LED Lamp

(i) Scenario 1: Replacing the old housing with a new one

In this model the old lamp is completely replaced by the new lamp. This means the new lamp environmental impact is composed of the new aluminium housing, the LED lamp, the associated circuit, the old housing, the old lamp (HSP bulb) and the associated electrical. The input data therefore comprises for both lamps. Table 1 shows the inventory for the new lamp. Data for each component for the old lamp was obtained by weighing and material identification.

Table 2: New Lamp Inventory⁸

Part	Component	Mass (kg)	Part	Component	Mass (kg)
Capacitors	Ballast	0.06	Housing (polypropylene)	Ballast	0.808
Zener diodes	Ballast	0.0012	PET fi	Ballast	0.046
Resistors	Ballast	0.12	Base	Ballast	2.52
Integrated circuit	Ballast	0.24	Metal clips	Fitting	0.692
Transistor	Ballast	0.036	Wiring	Fitting	0.231
Foam	Ballast	0.069	Copper pins	Fitting	0.0023
Inductor	Ballast	0.072	Base contacts	Lamp	0.009
Inductor	Ballast	0.048	Base contacts	Lamp	0.005
PCB (Al. machined tooled block)	Ballast	4.615	LED	Lamp	0.36
Wiring	Housing	0.046	Glass	Lamp	0.96
Solder paste	Ballast	0.023	Coating	Lens	0.012

Housing	Housing	0.84	Coating	Lens	0.012
Card	Packaging	0.069			

(i) Scenario 2: Remanufactured Old Lamp

In this model the old lamp is remanufactured. The major remanufacturing activities are disassembling, coating and assembling. In the disassembling all electrical components are removed and form part of waste which is handled differently. In the assembly process, the housing is fitted with new LED lamp and the associated circuit (ballast). Therefore the inventory for the remanufactured lamp includes the old housing, polyester, and the LED lamp and its associated electronics. The other part of LCI are the impact elements. These are the outputs from the analysis. They are obtained by characterisation. The output inventory is a comprehensive list of 1496 impact elements.

3. ENVIRONMENTAL IMPACT ANALYSIS

The impact elements are allocated to areas of impact. The analysis tool used is SimaPro 8.4. The impact assessment method is BEE+ V4.07. The impact category areas assessed are global warming, acidification, human health, eutrophication, ecotoxicity, photochemical smog, natural resource depletion, habitat alteration, ozone depletion and water intake

3.1. Results

3.1.1. Scenario 1:

Replacing the old lamp with a complete new one has a normalized overall impact of 2.59 pts (Figure 2). On a single score analysis, the also shows that eutrophication category is heavily impacted and the LED electronics are the major contributors (figure 2). It contributes 85% o the total impact.

1.1.1. Scenario 2

Remanufactured housing and fitting with new LED shows an overall impact of 2.194 pts The most impacted category is eutrophication and the major contributing component is the LED and associated circuit (figures 3).

2. DISCUSSION

2.1. Comparisons

Comparison of the two products shows that the New LED lamp has a higher impact in all categories than the remanufactured lamp. The new LED lamp has 0.366 pts more impact than the remanufactured lamp. This is due to the re-use of the old aluminium.

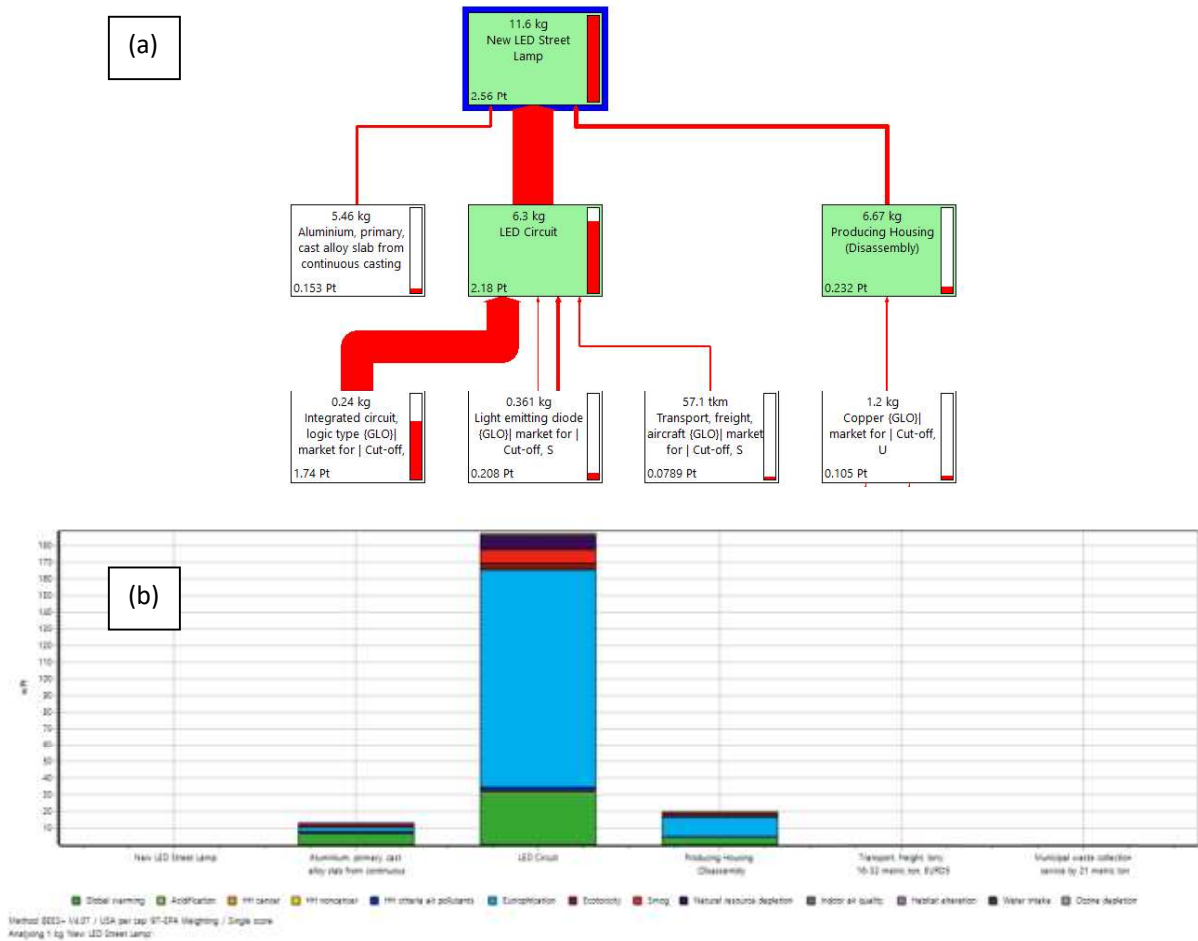


Figure 2: New Lamp Overall Impact (a) Process contribution (b) Single Core Contribution

In both cases it has been observed that the major contributing factor to the environment is the use of the new LED lamp with its associated electronics; the driver circuit in the lighting. The changes that are effected on the remanufactured housing do not have much impact on the environment unfriendly. The LED data is based on global factors. This is a generalised weakness because different countries have different impacts due to electricity mix among other factors.

The remanufacturing of the old lamp has little impact. The fact that the manufacturing process does not involve change material mass such as machining. Machining would mean using more energy and generating waste material. The processes do not include smelting which would also contribute to high energy use. The major factor that may have contributed to the increase in environmental impact of the remanufactured housing is the coating process. This is because it is the major difference between the two products. In both cases it is observed that the electronics have a major contribution to the environmental impact. This confirms the fact that the manufacturing of semiconductor products has a very high impact on the environment. It shows that the older high pressure lamp should not be replaced by the LED. However the LED lamp has a much bigger advantage over other lighting technologies in the use phase. Thus the LED would still be fitted even in the remanufactured lamp.

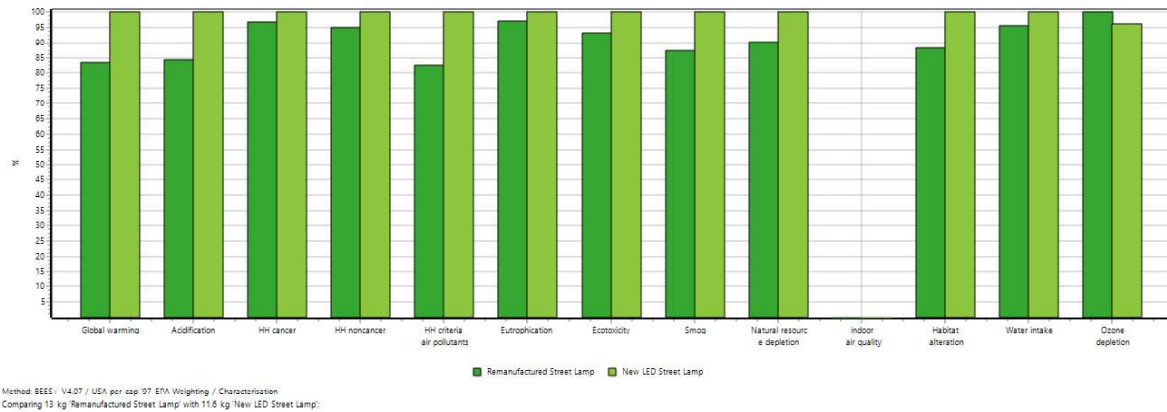


Figure 3: Characterization Comparison of New Lamp and Remanufactured Lamp

3. CONCLUSIONS

The study has shown that the remanufactured lamp has a lower environmental impact than the new lamp. Replacing it completely makes the new lamp to have a much higher environmental impact. The study has also shown that remanufacturing a product is environmentally friendly. Usually for a decision to remanufacture a product is reached based on comparison with other products. An LCA should be carried out for the remanufactured product and compare it with the other competing products. This study shows that comparison should also include environmental impact. The remanufacturing processes should be carefully be analysed and a decision made not only based on economic benefits nut also on environmental impact basis. Remanufacturing is therefore a serious option to consider when replacing a product in order to reduce product environmental impact.

4. REFERENCES

- 1 Ewan, W; Street Lighting Toolkit; Society of Chief Officers of Transportation Scotland; February 2013
- 2 Viaamse Instelling voor Technologisch Onderzoek; (1995); Life cycle assessment; Business and the Environment – Practitioner Series; Stanley Thornes; Cheltenham; UK
- 3 Giuseppe Ingarao et al; Environmental modelling of aluminium based components manufacturing routes: Additive manufacturing versus machining versus forming; Journal of Cleaner Production ; Volume 176, 1 March 2018, Pages 261-275.
- 4 Patricia Gómez et al; Influence of Composition on the Environmental Impact of a Cast Aluminium Alloy; Materials Journal; Published: 25 May 2016
- 5 Víctor C et al; The Influence of Different Recycling Scenarios on the Mechanical Design of an LED Weatherproof Light Fitting.
- 6 Leena T et al; Comparison of Life Cycle Assessments of LED Light Sources; Published in January 2012 in Journal of Light & Visual Environment 36(2) pages 44-54
- 7 International Organization for Standardization (ISO). (2006a). ISO 14040: Environmental management - Life cycle assessment - Principles and framework. Geneva, ISO.
- 8 Sabina A H, et al; Comparative Life Cycle Assessment (LCA) of streetlight technologies for minor roads in United Arab Emirates; Energy for Sustainable Development; published in 2013 pages 438–450